Search for the Decay of the 3.5 eV ^{229}Th^{m}

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Kroger and Reich [1] studied the α-decay of ^{233}U and proposed a ~100-eV level in ^{229}Th. More recently, Helmer and Reich [2,3] determined the energy of this level to be 3.5±1.0 eV. This extremely low energy makes such a level potentially useful for the study of the interactions between the nucleus and its environment. Possible decay modes of the 3.5-eV isomer are: photon emission to the ground state; an electron-bridge mechanism, where part of the decay energy is released by photons and the rest is absorbed by atomic electrons; and α decay to ^{225}Ra. Internal conversion decay is not possible because the excitation energy of the isomer is less than the binding energy of even the outermost electron in a thorium atom. However, in metallic thorium, decay through conversion electrons from the conduction band may take place. Several attempts to detect de-exciting optical photons in the range of 300-500 nm either produced erroneous results, or not definitive conclusions. No measurement of the 3.5-eV isomer half-life has yet been reported.

We present here a method to determine the half-life of ^{229}Th^{m} by measuring the effect of its isomeric decay on the α disintegration of ^{229}Th^{g} [4]. This method does not require detecting any radiation from the isomeric decay, but instead, is based on the growth in the α disintegration rate of ^{229}Th^{g} due to its delayed population from the 3.5-eV isomer.

The procedure consisted of chemically separating ^{229}Th from ^{233}U, letting fresh ^{229}Th (and its 3.5-eV isomer) grow for 14.5 hours, and then separating this new ^{229}Th to measure the intensity of the 193-keV γ ray (its most intense transition) as a function of time. We separated ^{229}Th from about 25 g of ^{233}U and measured its γ-ray spectrum with a 40% relative efficiency hyper-pure coaxial Ge detector. Our experiment was designed to search for the decay of ^{229}Th^{m} in a half-life range of ~8 hours to ~10 days. Figure 1 shows our experimental results together with the various growths of the activity expected for five different half-life values (between 6 hours and 5 days) assumed for the isomer. These data, however, do not suggest any activity growth. Moreover, a χ^2 statistical analysis gives an upper limit of 6 hours with a confidence level of 99% for the half-life of ^{229}Th^{m}. Alternatively, since we did not detect any activity growth, our results are also consistent with a very slow growth caused by the existence of an isomer with an extremely long half-life. In fact, by performing a similar analysis we have concluded that a ^{229}Th^{m} half-life of >20 days is also consistent with our data. In order to improve upon these results, ^{233}U with a substantially lower amount of ^{232}U is needed.

Footnotes and References

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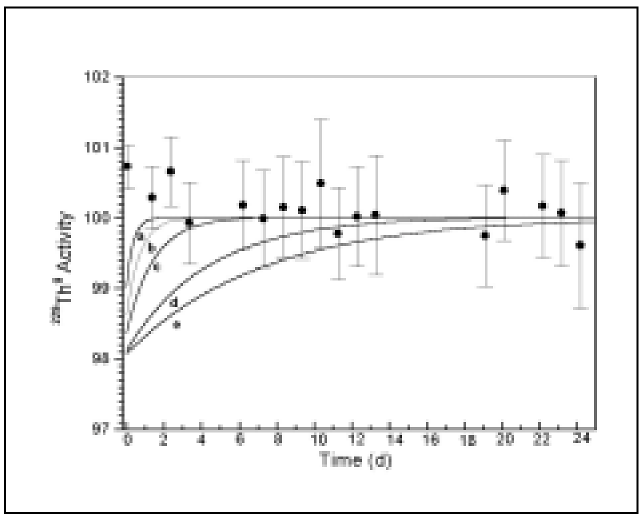

Fig. 1 Values of the 193-keV γ-ray intensity from ^{229}Th^{g} α decay measured at various times after chemical separation. Each of the five continuous curves represents the expected growth of the ^{229}Th^{g} activity for an assumed ^{229}Th^{m} half-life of: (a) 6 hours, (b) 12 hours, (c) 1 day, (e) 3 days, and (e) 5 days, respectively.